Impact of Land Use Change on selected Soil Properties of Mollisols in the Entre Ríos Province, Argentine

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1. Abstract

Pasture under native vegetation for extensive cattle rising has been traditionally a common land use in the Entre Ríos province (Argentine). However, in the last years increasing land surfaces have been incorporated to agricultural grain production. Moreover, cropping systems became more intensive, mainly because of the increase of soybean proportion in the rotations. The aim of this study was to assess soil use intensity effects on selected soil properties of Mollisols in a crop-pasture rotation experiment. Treatments included: 1) continuous cropping (CC), 2) crop-pasture rotation (CP), 3) permanent pasture (PP) and 4) native, never cultivated land (NV) as a reference. Soil samples were routinely analyzed for pH, C and N contents, extractable P, cation exchange capacity, soil physical properties (aggregate stability, percolation index, bulk density, and particle density) as well as pore size distribution by Hg intrusion and specific surface by N_2 adsorption isotherms. Significant changes in soil properties were recorded following the different land uses, which indicate that Mollisols are susceptible to physical degradation by land use changes. Natural vegetation, permanent pastures and pastures rotated with crops maintain higher storage porosity (50 – 0.5 μm) than continuous cropping. Natural vegetation and pastures also maintain a very high organic matter content contrasting with declined levels following continuous cropping. Soil storage porosity was correlated positively with organic matter content and aggregate stability. Avoiding continuous cropping by adoption of crop-pasture rotations is an adequate management practice for maintaining or even promoting the structure stability of the studied Mollisols.

2. Introduction

Pasture under native vegetation for extensive cattle rising has been traditionally a common land use in the Entre Ríos province (Argentine). However, in the last years increasing land surfaces have been incorporated to agricultural grain production. Moreover, cropping systems became more intensive, mainly because of the increase of soybean proportion in the rotations. After Vertisols, Mollisols are the most widespread soil type in Entre Ríos.

The quality of any soil depends in part on the soil´s natural or inherent composition, which is a function of geological materials and soil state factors or variables. In some cases, due to adverse management, human activities such as land use and farming practices can result in the deterioration of a soil that originally possessed good inherent quality (Carter *et al*., 1997). Therefore, the agricultural use causes modifications in the natural soil structure, which can condition its productivity. Soils with a high physical quality are characterized by a suitable distribution of pore sizes and a high total porosity (Kay, 1990). The aim of this study was to assess soil use intensity effects on selected soil properties of Mollisols in a crop-pasture rotation experiment. We focussed on soil pore size distribution changes.

3. Materials and methods

3.1 Site characteristics and management practices

Soil physical and chemical properties were evaluated on one soil Vertic Argiudoll from a dairy farm located in Entre Ríos province at 32º 04' S and 60º 01' W. Agricultural soils were compared with contiguous natural undisturbed soils. Treatments included: 1) continuous cropping (CC), 2) crop-pasture rotation (CP), 3) permanent pasture (PP) and 4) native, never cultivated land (NV) as a reference. Soybean and sorghum were the main crops in the rotation and zero tillage was the tillage system in the last year before sampling.

3.2 Laboratory and fields methods

Three composite soil samples were taken at the 0-12 cm depth. Soil sampling was performed both disturbed and undisturbed for routine soil general properties and soil aggregate stability analysis, respectively. Samples were air-dried and passed through a 2000 μm sieve. Particle size distribution was determined by the pipette method. Organic carbon content (OC) was determined by the Walkley and Black method, soil pH using a 1: 2.5 soil to water ratio and total nitrogen (N) according to Kjeldahl. Extractable phosphorus was measured according to Bray-Kurtz methods and CEC was determined after extraction with ammonium acetate.

Aggregate structural stability was determined by the Henin test, in three subsamples treated differently, i. e. no pretreatment before sudden water immersion (SAW), pretreatment with ethanol (SAE) and pretreatment with benzene (SAB). Results of the three tests were used for calculating the instability index. The K percolation index was also assessed. Soil bulk density, ρm, was determined by the core method and particle density, ρs, by the picnometer method. Total porosity (TP) was calculated from ρm and ρs, as well as pore size distribution by Hg intrusion Different ranges of pore sizes were taken into account, according with Greenlad (1977), was estimated. Specific surface area (SS) by N_2 adsorption isotherms was determined.

3.3 Statistics

Variance analysis for assessing soil use and management effects were carried out using ANOVA and the selected indicators were evaluated by means of the Tukey test at the 5% significance level. Regression analysis was used to assess relationships soil variables.

4. Results and Discussion

Significant changes in soil properties were recorded following the different land uses, which indicate that Mollisols are susceptible specially to physical degradation by land use changes (Table 1). The inclusion of crops in the rotations caused significant losses in the pores size for the categories $P(_{50-0.5\mu m})$ and $P(_{10-0.2\mu m})$, whereas in the other analyzed categories significant changes were not observed.

The soil in natural vegetation condition exhibited greater aggregate stability. Losses of organic matter during cultivation influenced the studied soil physical properties. Natural vegetation, permanent pastures maintain higher storage porosity, than continuous cropping and pastures rotated with crops (Fig. 1).

Table 1 Impact of land use changes as assessed by sensitivity analysis of soil chemical and physical properties of the study soils

Soil variables	Level of significance	Soil variables	Level of significance
Organic carbon	*<0.0001*	**SAW**	*0.0002*
pH	*0.0012*	**SAE**	*0.0030*
Total N	*0.0001*	**SAB**	*<0.0001*
OC/TN ratio	*0.1886*	**Instability index**	*0.0001*
Extractable P	*<0.0001*	**K percolation index**	*0.0002*
Total Porosity	*<0.0001*	**CEC**	*0.1166*
Porosity 100 – 50 µm	*0.7558*	**Bulk Density**	*0.0003*
Porosity 100 – 30 µm	*0.7307*	**Soil losses**	*0.0001*
Porosity 100 – 10 µm	*0.4167*	**Specif surface**	*<0.0001*
Porosity 50 – 0.5 µm	*0.0016*	**Potential minerable N**	*0.2069*
Porosity 10 – 0.2 µm	*0.0030*		

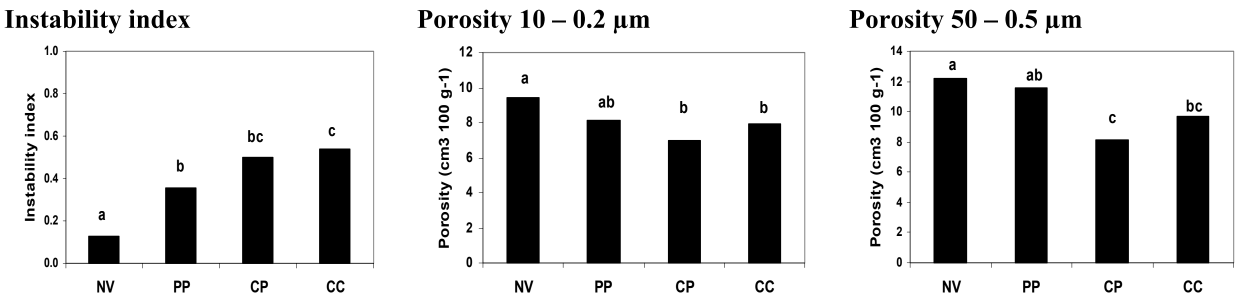

Figure 1 Effect of soil use on stability structural and pore size distribution

Correlation matrix for all the studied variables is shown in Table 2. For 42 out of 121 soil attribute pairs analyzed a significant relationship was found ($P < 0.05$). Highest positive correlations coefficients were obtained for OC versus N, K and $P(_{10-0.2\mu m})$, ρ_m versus Is and SS ($r>0.84$). Highest negative correlations were obtained for

OC versus Is, ρ_m and SS, SS versus $P_{(50\text{-}0.5\mu m)}$, $P_{(10\text{-}0.2\mu m)}$, and TP, ρ_m versus $P_{(50\text{-}0.5\mu m)}$ and $P_{(10\text{-}0.2\mu m)}$, (r>0.84). Moreover, soil storage porosity was correlated with OC, N, Is, Ks, TP, pot min N.

Table 2 Correlation matrix between soil properties on a Vertic Mollisol.

	OC	*SS*	*P*	*pH*	*N*	*CEC*	*Is*	*Ks*	ρ_m	*PT*	*N pot. min*	$P_{(100\text{-}50)}$	$P_{(100\text{-}30)}$	$P_{(100\text{-}10)}$	$P_{(50\text{-}0.5)}$	$P_{(10\text{-}0.2)}$
OC	1															
SS	-0.90	1														
P	-0.28	-0.13	1													
pH	0.03	-0.33	0.72	1												
N	0.98	-0.91	-0.22	0.08	1											
CEC	0.20	-0.07	-0.47	-0.63	0.20	1										
Is	-0.88	0.94	-0.02	-0.18	-0.89	-0.36	1									
KS	0.85	-0.87	-0.10	0.09	0.86	0.34	-0.90	1								
ρ_m	-0.87	0.95	-0.13	-0.40	-0.89	0.03	0.85	-0.78	1							
TP	0.81	-0.96	0.30	0.48	0.83	-0.16	-0.83	0.76	-0.96	1						
N pot. min	0.52	-0.67	0.26	-0.01	0.55	0.22	-0.60	0.62	-0.63	0.65	1					
$P_{(100\text{-}50\mu m)}$	-0.15	0.14	0.21	0.23	-0.16	0.08	0.05	-0.24	0.07	-0.11	0.00	1				
$P_{(100\text{-}30\mu m)}$	-0.18	0.13	0.31	0.26	-0.18	0.08	0.04	-0.23	0.06	-0.09	0.04	0.99	1			
$P_{(100\text{-}10\mu m)}$	-0.23	0.09	0.49	0.40	-0.21	-0.04	0.04	-0.25	0.02	-0.02	0.10	0.95	0.98	1		
$P_{(50\text{-}0.5\mu m)}$	0.70	-0.90	0.41	0.54	0.73	-0.11	-0.80	0.68	-0.85	0.91	0.70	0.11	0.13	0.22	1	
$P_{(10\text{-}0.2\mu m)}$	0.84	-0.90	0.04	0.29	0.86	-0.01	-0.78	0.73	-0.88	0.87	0.68	-0.12	-0.14	-0.10	0.90	1

OC = organic carbon content; SS = specific surface area; P = extractable phosphorus; pH in a 1: 2.5 soil: solution ratio; N= total Nitrogen; Is = instability index according to Hénin; Ks = percolation index according to Henin; ρ_m = bulk density; TP = total porosity; N pot min = potential minerable Nitrogen; CEC = cation exchange capacity; $P_{(100\text{-}50\mu m)}$; $P_{(100\text{-}30\mu m)}$; $P_{(100\text{-}10\mu m)}$; $P_{(50\text{-}0.5\mu m)}$; $P_{(10\text{-}0.2\mu m)}$ = porosity in the 100-50, 100-30, 100-10, 50-0.5 and 10-0.2 µm range.

5. Conclusions

Increasing crop proportion in the rotation resulted in soil degradation at the medium term and threatened the sustainability of the soil resource at the long term.

The inclusion of crops in the rotations caused significant losses in the organic matter (OC and N) influenced the soil physical properties, i.e. aggregate structural stability and pores size for the categories between 50 to 0.5 µm and 10 to 0.2 µm.

Avoiding continuous cropping by adoption of crop-pasture rotations is an adequate management practice for maintaining or even promoting the structure stability of the studied Mollisols.

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